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Step 1: Human System Integration Functional Requirements Document, Rev. 2

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Abstract:
This Functional Requirements Document (FRD) establishes a minimum set of Human System Interface (HSI) functional requirements to achieve the Access 5 Vision of "operating High Altitude, Long Endurance (HALE) Unmanned Aircraft Systems (UAS) routinely, safely, and reliably in the National Airspace System (NAS)". Basically, it provides what functions are necessary to fly UAS in the NAS. The framework used to identify the appropriate functions was the "Aviate, Navigate, Communicate, and Avoid Hazards" structure identified in the Access 5 FRD. As a result, fifteen high-level functional requirements were developed. In addition, several of them have been decomposed into low-level functional requirements to provide more detail.

Status:

WP – Work in Progress Draft

Limitations on use:
There are several caveats that apply to this FRD. First, the document is intended to describe functional requirements for Step 1 only (en route operations above FL 430). Second, this document was developed with the assumption that the UAS has very little-to-no autonomy. This is important to recognize because the allocation of functions and roles of the UAS pilot and the system change as the system becomes more autonomous. And finally, this document makes the assumption that there is a 1:1 pilot-to-unmanned aircraft ratio. Although controlling multiple unmanned aircraft by one pilot is definitely an advantage for UAS manufacturers, it is not considered as a part of Step 1 for Access 5.

DRAFT
Step 1: Human System Interface (HSI) Functional Requirements Document (FRD)

Access 5
Technology Integrated Product Team
Human Systems Integration Work Package

January 2006
Version 2

The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

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RECORD OF CHANGES

Revision	Date	Change Description
Version 0.0	January 2005	A document entitled "HSI Functional Requirements and Design Guidelines for Remotely Operated Aircraft (ROA) C3 and CCA Sub-systems" was released and used as a guide in the development of this document.
Version 1.0	June 2005	Initial release of an overall HSI Functional Requirements Document.
Version 1.1	July 2005	Incorporates feedback from several members of the HSI Work Package and the Technology IPT lead.
Version 1.2	August 2005	Corrected minor errors and added an Executive Summary in preparation for delivery to the Systems Engineering Integration Team (SEIT).
Version 1.3	September 2005	Made modifications to the document based upon the SEIT's review.
Version 1.4	January 2006	Incorporated appendices into the main body and changed the document structure to align with the most recent Access 5 FRD (Version 2, Sept. 2005).

The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The purpose of this Functional Requirements Document (FRD) is to establish a minimum set of Human System Interface (HSI) functional requirements to achieve the Access 5 Vision of "*operating High Altitude, Long Endurance (HALE) Unmanned Aircraft Systems (UAS) routinely, safely, and reliably in the National Airspace System (NAS)*". Basically, it provides what functions are necessary to fly UAS in the NAS. It will also be used as a framework for technology interface requirements and design guidelines. See Table 1 for the complete list of the high-level functional requirements.

Requirement	The Human System Interface shall:
Aviate	
3.1.1	Enable the pilot to command maneuvers
3.1.2	Convey information to the pilot to monitor maneuvers
Navigate	
3.2.1	Enable the pilot to control the navigation system
3.2.2	Convey information to the pilot to determine the unmanned aircraft's position, ground track, and ground speed
Communicate	
3.3.1	Enable the pilot to communicate with ATC
3.3.2	Enable the pilot to control the communication system
3.3.3	Convey the status of the communication system to the pilot
Avoid Hazards	
3.4.1	Enable the pilot to control the cooperative collision avoidance (CCA) system
3.4.2	Convey information to the pilot to avoid cooperative aircraft
3.4.3	Control environmental information sources
3.4.4	Convey environmental status to the pilot
Cross-Cutting	
3.5.1	Enable the pilot to secure the aircraft control station
3.5.2	Convey information to the pilot to determine the health and status of the UAS
3.5.3	Enable the pilot to contact the unmanned aircraft
3.5.4	Enable the pilot to manage contingencies

Table 1: HSI High-Level Functional Requirements

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this Functional Requirements Document (FRD) is to establish a minimum set of Human System Interface (HSI) functional requirements to achieve the Access 5 Vision of "*operating High Altitude, Long Endurance (HALE) Unmanned Aircraft Systems (UAS) routinely, safely, and reliably in the National Airspace System (NAS)*".

Furthermore, it provides a framework to derive technology interface requirements and design guidelines also being developed by the Human Systems Integration Work Package. The HSI functional requirements in this document will also be verified through Flight Demonstrations and Aircraft Control Station (ACS) Simulations performed by Access 5. Figure 1 below shows the relationship between this document and the other Human Systems Integration Work Package activities.

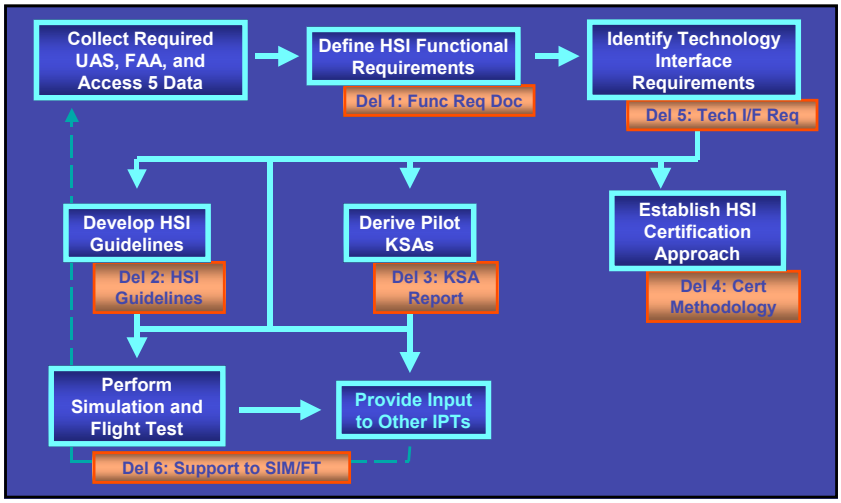

Figure 1:Relationship of HSI Tasks and Deliverables

The scope of this document is to identify the Human System Interface functional requirements for only Step 1 of Access 5 (see Section 1.2 for a full explanation of the Access 5 steps). This means that these functional requirements apply to UAS operations for routine flight above Flight Level (FL) 430.

1.2 ACCESS 5 OVERVIEW

Access 5 is a national project sponsored by the National Aeronautics and Space Administration (NASA) and Industry with participation by the Federal Aviation Administration (FAA), Department of Defense (DoD) and Department of Homeland Security (DHS) promoting the safe and reliable operation of HALE UAS within the NAS for civil and commercial applications. This team of government and industry partners will focus their resources on developing the necessary technology, policies, and regulations to enable companies to apply for FAA certification and approval to operate their civil/commercial UAS in the NAS.

The Access 5 Project is taking an incremental approach for introducing UAS into the NAS. HALE was chosen as the focus because HALE aircraft are mature systems and can operate above most air traffic, making this class of UAS the safest for initial introduction into the NAS. It is believed, however, that Access 5 will also lay the groundwork for the future introduction of other classes of UAS. Access 5 will achieve its goals by systematically addressing access to the NAS in four discrete steps of increasing complexity and capability:

Step 1: Routine Operations above FL 430 through Pre-Coordinated Airspace

Step 2: Routine Operations above FL 180 through Pre-coordinated Airspace with Emergency Landings at Pre-coordinated Airports

Step 3: Routine Operations above FL 180 through C, D, and E Airspace with Emergency Landing at Pre-coordinated Airports

Step 4: Routine Operations above FL 180 through C, D, and E Airspace with Emergency Landings at any UAS Designated Airport

1.3 DOCUMENT ORGANIZATION

This document is organized into the following sections:

Section 1 – Introduction: States the purpose, scope, and background of this requirements document, including its relationship to the Access 5 project.

Section 2 – Methodology: States the methodology used to develop the requirements.

Section 3 – HSI Functional Requirements: Specifies the HSI functional requirements for a UAS in accordance with the four major functions and cross-cutting requirements identified in the Access 5 FRD.

Section 4 – Traceability Matrix: Provides traceability between each HSI functional requirement and the functional requirements found in the Access 5 FRD.

Section 5 – Verification Matrix: Provides the recommended means for verifying each functional requirement.

2 METHODOLOGY

Several steps were taken to develop the HSI functional requirements. The first step was to perform a functional analysis of a "notional" UAS. The structure chosen by the Access 5 System Engineering Integration Team (SEIT) was a model similar to what aviators use today. The four high-level functions identified were: *Aviate, Navigate, Communicate, and Avoid Hazards*. From these four high-level functions, low-level functions and appropriate requirements were developed by the individual work packages.

Once the functional analysis and appropriate requirements were established, the next step was to determine the role the Human System Interface would play. An analysis was performed in each functional area to determine if a Human System Interface requirement was necessary. Each requirement was written such that it did not specify design solutions or require/limit equipment in the UAS.

The process used to identify the requirements was to evaluate if one of two types of Human System Interface functions were necessary. The first type of function is having the ability to convey information that the UAS pilot needs to process to enable him/her to make a decision. And in reverse, control functions are necessary as well. These functions enable the pilot to command the unmanned aircraft to aviate, navigate, communicate, and avoid hazards. Therefore, each functional requirement will begin with either "The Human System Interface shall convey (some type of information) to the pilot" or "The Human System Interface shall enable the pilot to control (some type of system)". (See Figure 2 below)

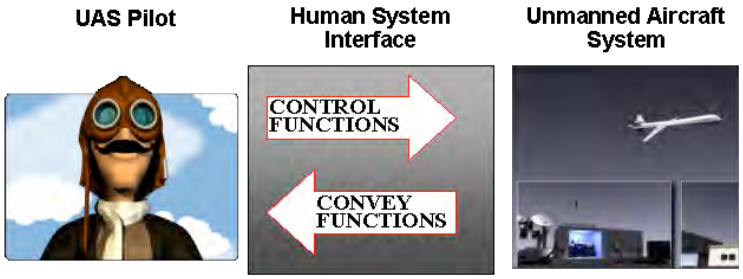

Figure 2: HSI Functions

In performing this analysis, it was also critical to identify where "gaps" are when placing the pilot outside the aircraft and in an aircraft control station. To help highlight these gaps, a note is made that states the requirement is different/above the requirements for manned aircraft.

2.1 ASSUMPTIONS

First, this document assumes that the system has very little to no autonomy. The reason for this assumption is that "It is likely that no single standard will fit all [UAS], but rather these standards must be based on vehicle autonomy."[1] This is important to recognize because the allocation of functions and roles of the UAS pilot and the system change as the system becomes more autonomous. Therefore, this document will serve as a baseline with most, if not all, of the functions and roles being placed upon the UAS pilot. Future work could be

[1] Olson, Wesley A. and Mark G. Wuennenberg. "Autonomy Based Human-Vehicle Interface Standards for Remotely Operated Aircraft."

explored in this area by evaluating how the HSI functions change as the systems become more autonomous.

A second assumption this document makes is that there is a 1:1 pilot-to-unmanned aircraft ratio. Although controlling multiple unmanned aircraft by one pilot is definitely an advantage for UAS manufacturers, it is not considered as a part of Step 1 for Access 5.[2] Hopefully, future work will evaluate how requirements are added/deleted/changed as more research in this technological area is explored.

[2] "Major Program Decisions" slide from SEIT FY05 Midterm presentation dated 17 March 2005

3 HSI FUNCTIONAL REQUIREMENTS

3.1 AVIATE

Below are the Human System Interface functional requirements related to the Aviate function.

3.1.1 COMMAND MANEUVERS

The Human System Interface shall enable the pilot to command maneuvers.

Note: This requirement is the foundation for the Aviate function in that it allows the pilot to command the unmanned aircraft to change its flight or ground path. It also is consistent with the program assumption that "An operator will be in or on the loop during normal [UAS] operations".[3]

3.1.1.1 Control Aircraft Spatial Orientation

The Human System Interface shall enable the pilot to control the spatial orientation of the unmanned aircraft. Controlling the spatial orientation of the unmanned aircraft includes, but is not limited to directly or indirectly controlling the unmanned aircraft's attitude, heading, and engine power, as required, for both ground and air operations[4].

Note: This requirement is necessary because it allows the pilot to control the spatial orientation of the unmanned aircraft.

3.1.1.2 Control Aviate Systems

The Human Systems Interface shall enable the pilot to control aviate systems settings. An aviate system is defined as any system that contributes, in part or as a whole, to performing the Aviate function.

Note: This requirement is necessary because it allows the pilot to control the state of any of the systems that contribute to the Aviate function. This could include, but is not limited to, the propulsion system, fuel system, electrical system, environmental systems such as de-icing or anti-icing, airframe configuration and redundant or emergency systems.

3.1.2 MONITOR MANEUVERS

The Human System Interface shall convey information to the pilot to monitor maneuvers.

Note: This requirement compliments Section 3.1.1 because it enables the pilot to determine how the unmanned aircraft is flying in relation to its three axes (pitch, roll, and yaw).

[3] Access 5. "HALE ROA Concept of Operations". 30 September 2003
[4] Air Force Manual 11-217 Volume 1, 3 January 2005, Basic Instrument Flying

3.1.2.1 Convey Spatial Information

The Human System Interface shall convey spatial information to the pilot. Spatial information includes, but is not limited to the unmanned aircraft's attitude, altitude, heading, airspeed, angle-of-attack, and vertical velocity.[5]

Note: This requirement is necessary because it provides one type of essential information for the pilot to maintain situational awareness. This specific information will enable the pilot to determine whether or not changes to the flight path are being received and executed. It is also the "Convey Function" that compliments the "Control Function" in Section 3.1.1.1.

There are four other types of information as identified by Mica Endsley. The other four types of information will be identified throughout this document.

3.1.2.2 Convey Aviate Systems Status

The Human System Interface shall convey aviate systems status to the pilot. Aviate systems statuses include, but are not limited to the status of the propulsion system, the fuel system, the electrical system, airframe configuration, and redundant or emergency systems.

Note: This requirement is necessary because it provides information to the pilot on specific systems required to manage the flight of the unmanned aircraft. It is also the "Convey Function" that complements the "Control Function" in section 3.1.1.2.

3.2 NAVIGATE

Below are the Human System Interface functional requirements related to the Navigate function.

3.2.1 CONTROL NAVIGATION SYSTEM

The Human System Interface shall enable the pilot to control the navigation system.

Note: This requirement is necessary because it allows the pilot to plan, operate and change the navigational state of the unmanned aircraft. The navigational state refers to how the unmanned aircraft is following the mission/flight plan and the specifics of the mission/flight plan.

3.2.1.1 Develop Mission/Flight Plan

The Human System Interface shall enable the pilot to develop the mission/flight plan.

Note: This requirement reflects an assumption of Access 5 that states, "all [UAS] will be conducted on an instrument flight rules (IFR) flight plan."[6] Therefore, the pilot must be able to file a flight plan. The term "mission" is also added in that pre-flight planning will go well beyond filing a flight plan. Other activities may include assigning satellite frequencies for the C2 links, payload implementation, and identifying divert-airfields.

[5] Endsley, Mica R. "Situational Awareness In Aviation Systems." Handbook of Aviation Human Factors. 1999
[6] Access 5. "HALE ROA Concept of Operations". 30 September 2003

3.2.1.2 Operate Navigation System

The Human System Interface shall enable the pilot to operate the navigation system. Operating the navigation system is defined as managing the navigation mode, settings, or guidance method needed to execute the flight plan. Examples would include, but are not be limited to, inertial navigation system (INS), global positioning system (GPS), VHF Omni-directional Range (VOR) NAVAIDS and distance measuring equipment (DME), omni bearing selector (OBS) course, channel and frequency.

Note: This requirement is necessary because it allows the pilot to select the required navigation mode and settings to execute the mission as planned or required due to environmental changes and/or ATC requirements.

3.2.1.3 Update / Modify Flight Plan

The Human System Interface shall enable the pilot to update or modify the flight plan. Altering the flight plan can include changing a waypoint or multiple waypoints, the flight path necessary to fly to those waypoints, loiter points, or the final destination.

Note: This requirement is necessary because it allows the pilot to change the planned course, speed, and/or altitude of the unmanned aircraft for a number of reasons that include following an Air Traffic Control (ATC) directive, a change in its mission/destination, or bad weather along the flight path.

3.2.2 CONVEY POSITION

The Human System Interface shall convey information to the pilot to determine the unmanned aircraft's position, ground track, and ground speed.

Note: This requirement identifies where the unmanned aircraft is flying in relation to its geographic location. After this information is conveyed, the pilot can determine if the unmanned aircraft is following the mission/flight plan or if a correction is needed.

3.2.2.1 Convey Navigation System Information

The Human System Interface shall convey navigational information to the pilot. Navigational information includes, but is not limited to the location of the unmanned aircraft, terrain features, airspace, airports, population centers, waypoints, routes, and navigation fixes.[7]

Note: This requirement is necessary because it provides the second type of essential information for the pilot to maintain situational awareness. This specific information will enable the pilot to determine the current navigational state of the unmanned aircraft.

3.3 COMMUNICATE

Below are the Human System Interface functional requirements related to the Communicate function.

[7] Endsley, Mica R. "Situational Awareness In Aviation Systems." Handbook of Aviation Human Factors. 1999

3.3.1 COMMUNICATE WITH ATC

The Human System Interface shall enable the pilot to communicate with ATC. This requirement refers to the current two-way radio communication requirement as well as current and future digital and text based communication systems.

Note: This requirement is necessary because it meets Federal Aviation Regulation (FAR) Part 91.135, "Each pilot must maintain two-way radio communications with ATC while operating in Class A airspace."[8] *In addition, this requirement supports the Avoid Hazards function in that it will allow for aircraft deconfliction via communication with ATC.*

3.3.2 CONTROL COMMUNICATION SYSTEM

The Human System Interface shall enable the pilot to control the communication system.

Note: This requirement will be further broken down into three specific functions required to control the radio. In addition, the functional requirement from the ATC Communications FRD will be cited.

3.3.2.1 Tune the Radio to Assigned ATC Channel

The Human System Interface shall enable the pilot to tune the radio to an assigned ATC channel.[9]

Note: RTCA DO-186A states that the radio must be tunable between 118.0000 MHz and 136.9750 MHz at 25 and/or 8.33 kHz spacing.[10]

3.3.2.2 Monitor ATC Channel Activity

The Human System Interface shall enable the pilot to monitor ATC channel activity.[11]

Note: This assumes voice communications is the means to communicate with ATC. This may change in the future as communications may be transmitted using data packets. However, currently there is no requirement to have a data-link capable communications system for IFR flight operations in the NAS.

3.3.2.3 Transmit Voice

The Human System Interface shall enable the pilot to transmit voice on the assigned ATC channel.[12]

Note: Comment found in 3.3.2.2 applies for the transmit function as well.

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[8] "Part 91.135: Operations in Class A Airspace" FAR/AIM 2004. 2004

[9] Access 5. "HALE ROA ATC Communications: Step 1 Functional Requirements Document." Section 4.2.1. 31 May 2005

[10] RTCA Inc. "DO-186A: Minimum Operational Performance Standards for Airborne Radio Communications Equipment Operating Within the Radio Frequency 117.975 – 137.000 MHz." Change 2. 05 March 2002

[11] Access 5. "HALE ROA ATC Communications: Step 1 Functional Requirements Document." Section 4.2.2. 31 May 2005

[12] Access 5. "HALE ROA ATC Communications: Step 1 Functional Requirements Document." Section 4.2.4. 31 May 2005

3.3.3 CONVEY COMMUNICATION SYSTEM STATUS

The Human System Interface shall convey the status of the communication system to the pilot. This means the pilot, at any time, has the ability to determine whether or not the communication equipment is functioning properly.

Note: This functional requirement allows for the incorporation of current and future digital text communication (examples are: CPDLC, ACARS and emerging technologies). It is also the "Convey Function" that compliments the "Control Function" in Section 3.3.2.

3.4 AVOID HAZARDS

Below are the Human System Interface functional requirements related to the Avoid Hazards function. The hazards addressed in Access 5 Step 1 are cooperative aircraft and hazardous weather. Cooperative aircraft are defined as those aircraft that transmit a signal from their onboard Mode A, C, or S transponder or data link transceiver. Hazardous weather is defined as weather that poses a hazard to the unmanned aircraft and can include thunderstorms, precipitation, high winds, turbulence, icing, etc.

3.4.1 CONTROL COLLISION AVOIDANCE SYSTEM

The Human System Interface shall enable the pilot to control the cooperative collision avoidance (CCA) system.

Note: This requirement is necessary because it allows the pilot to configure the settings and surveillance volume required.

3.4.2 CONVEY COLLISION AVOIDANCE INFORMATION

The Human System Interface shall convey information to the pilot to avoid cooperative aircraft.

Note: This requirement is necessary because it provides the third type of essential information for the pilot to maintain situational awareness. Although Mica Endsley identifies it as "Tactical SA", some of the elements apply to avoiding other aircraft such as detection and prioritization of different threats.[13] *In addition, this functional requirement is broken down into four elements of information listed below. Each of them is required for the pilot to avoid cooperative aircraft for a low-level of autonomy CCA system.*

3.4.2.1 Convey Location of Cooperative Aircraft

The Human System Interface shall convey the relative location of all cooperative aircraft within the CCA system's surveillance volume to the pilot. A cooperative aircraft is defined as an aircraft possessing an onboard transponder or other system, which provides positioning information in 3-D space to ATC and other aircraft. The surveillance volume will be specific to the design of the CCA system.

[13] Endsley, Mica R. "Situational Awareness In Aviation Systems." Handbook of Aviation Human Factors. 1999

Note: This requirement is based upon the first function of cooperative collision avoidance, which is to detect the traffic. This requirement then adds the requirement of conveying that information to the pilot.[14]

3.4.2.2 Convey Track Information

The Human System Interface shall convey the track profiles associated with any of the cooperative aircraft detected. The track profile includes, but is not limited to, its heading, airspeed, and altitude.

Note: This requirement is based upon the second function of cooperative collision avoidance, which is to track traffic. This requirement then adds the requirement of conveying that information to the pilot.[15]

3.4.2.3 Convey Collision Potential

The Human System Interface shall convey that the potential for a collision exists.

Note: This requirement is based upon the third function of the cooperative collision avoidance, which is evaluating collision potential. This requirement then adds the requirement of conveying that information to the pilot.[16] *Common methods include audible tones, flashing lights on a display, or change in the way a track profile is displayed.*

3.4.2.4 Convey Guidance Commands

The Human System Interface shall convey guidance commands to avoid the potential for a collision.

Note: This requirement is based upon the fifth function of the cooperative collision avoidance, which is determining the avoidance maneuver. This requirement then adds the requirement of conveying that information to the pilot.[17]

3.4.3 CONTROL ENVIRONMENTAL INFORMATION SOURCES

The Human System Interface shall enable the pilot to control environmental information sources.

Note: The sources can range from sensors providing real time weather information on board the aircraft to external sources such as commercial weather information providers on the Internet. In either case, the pilot must be able to gather, tailor, and manipulate appropriate information to avoid hazardous weather.

3.4.4 CONVEY ENVIRONMENTAL INFORMATION

The Human System Interface shall convey environmental status to the pilot. Environmental status includes, but is not limited to weather formations, temperature, icing, cloud conditions, visibility, turbulence, and winds.[18]

[14] Access 5. "FY 05 End of Year Briefing for Collision Avoidance." Slide 16. 23 Aug 2005
[15] Access 5. "FY 05 End of Year Briefing for Collision Avoidance." Slide 16. 23 Aug 2005
[16] Access 5. "FY 05 End of Year Briefing for Collision Avoidance." Slide 16. 23 Aug 2005
[17] Access 5. "FY 05 End of Year Briefing for Collision Avoidance." Slide 16. 23 Aug 2005
[18] Endsley, Mica R. "Situational Awareness In Aviation Systems." Handbook of Aviation Human Factors. 1999

Note: This requirement is necessary because it provides the fourth type of essential information for the pilot to maintain situational awareness. This specific information will enable the pilot to determine whether or not the environment near and around the aircraft is sufficient to conduct safe flight and alter the flight path if necessary.

3.5 CROSS-CUTTING FUNCTIONS

Some UAS functions are common to all four of the high level functions (aviate, navigate, communicate, and avoid hazards). The human systems interface functions that can be categorized this way are discussed in this section.

3.5.1 SECURE AIRCRAFT CONTROL STATION

The Human System Interface shall enable the pilot to secure the aircraft control station.

Note: This functional requirement is necessary because it allows the pilot to have the means to provide physical security to the ACS to limit the potential for a high-jacking. In manned aircraft, this is accomplished through a secure cockpit or every passenger having proper credentials. Although there may be many different implementations, the rationale stated should be kept in mind.

3.5.2 CONVEY HEALTH AND STATUS

The Human System Interface shall convey information to the pilot to determine the health and status of the UAS.[19]

Note: This requirement is necessary because it provides the fifth type of essential information for the pilot to maintain situational awareness. This specific information will enable the pilot to determine whether or not systems are functioning properly and responding to inputs. Any degradation of a system that could decreases the UAS's ability to operate normally should be brought to the pilot's attention. It is also the "Convey Function" that compliments the "Control Function" in Sections 3.1.1, 3.2.1, and 3.3.1.

3.5.3 ENABLE CONTACT WITH THE UNMANNED AIRCRAFT

The Human Systems Interface shall enable the pilot to contact the unmanned aircraft.

Note: This functional requirement is necessary because it identifies the capability of the pilot to send commands to the unmanned aircraft and receive feedback at an appropriate time. Two instances where multiple pilots are contacting the unmanned aircraft are specified below.

3.5.3.1 Transition Between Modes of Operation

The Human System Interface shall enable the pilot to transition between modes of operation. The pilot must be able to ensure the unambiguous hand-off between line-of-sight (LOS) and beyond-line-of-sight (BLOS) operations.

[19] Endsley, Mica R. "Situational Awareness In Aviation Systems." Handbook of Aviation Human Factors. 1999

Note: This functional requirement is unique to UAS operations. Since it is assumed that a BLOS means of command and control will be necessary to transit the NAS, special attention must be given to the transition between LOS to BLOS operations.

3.5.3.2 Transition Between Different Operating Locations

The Human System Interface shall enable the pilot to transition between different operating locations. The pilot must be able to ensure the unambiguous hand-off between different aircraft control stations.

Note: This functional requirement is also unique to UAS operations. It is also similar to the previous requirement except that pilot operations of the UAS may change from one operating location to another.

3.5.4 MANAGE CONTINGENCIES

The Human System Interface shall enable the pilot to manage contingencies.

Note: This requirement is necessary because it allows the pilot to respond to contingencies in a predictable manner. Each contingency that arises will provide appropriate information to be conveyed to the pilot.

4 TRACEABILITY MATRIX

The table below shows how each of the Human System Interface requirements traces to a functional requirement that was identified in the September 2005 Access 5 FRD.

HSI FRD Para. #	Functional Requirement	Access 5 FRD Para. #	Program Functional Requirement
Aviate			
3.1.1	Command Maneuvers	5.1.2	Maneuver
3.1.1.1	Control Aircraft Spatial Orientation	5.1.2.1 5.1.2.2	Maneuver in the Air Maneuver on the Surface
3.1.1.2	Control Aviate Systems	5.1.2.3	Enable the Pilot to Maneuver UA
3.1.2	Monitor Maneuvers	5.1.2	Maneuver
3.1.2.1	Convey Spatial Information	5.1.2.4	Enable the Pilot to Monitor Flight Operations
3.1.2.2	Convey Aviate System Status	5.1.2.4	Enable the Pilot to Monitor Flight Operations
Navigate			
3.2.1	Control Navigation System	5.2.5	Execute Navigation Command
3.2.1.1	Develop Mission/Flight Plan	5.2.1	Develop Mission Plan
3.2.1.2	Operate Navigation System	5.2.3	Determine How to Transition to Destination
3.2.1.3	Update/Modify Flight Plan	5.2.7.1	Pilot Updates to the Flight Plan
3.2.2	Convey Position	5.2.6	Convey Navigational Status
3.2.2.1	Convey Navigation System Information	5.2.6.1	Convey Navigational Information to the Pilot
Communicate			
3.3.1	Communicate with ATC	5.3.2	Communicate Outside the UAS
3.3.2	Control Communication System	5.3.2	Communicate Outside the UAS
3.3.2. 1	Tune the Radio to Assigned ATC Channel	5.3.2.1	Tune Radio to Assigned Channel
3.3.2.2	Monitor ATC Channel Activity	5.3.2.2.1	Receive Using Human Systems Interface
3.3.2.3	Transmit Voice	5.3.2.3.4	Transmit Using Human Systems Interface
3.3.3	Convey Communication System Status	-	-

Avoid Hazards			
3.4.1	Control Collision Avoidance System	5.4.2.3.6.1	Control the Collision Avoidance System
3.4.2	Convey Collision Avoidance System Information	5.4.2.3.5.1	Convey Threat Information to the Pilot
3.4.2.1	Convey Location of Cooperative Aircraft	5.4.2.3.1	Detect Traffic
3.4.2.2	Convey Track Information	5.4.2.3.2	Track Traffic
3.4.2.3	Convey a Collision Potential	5.4.2.3.3	Evaluate Collision Potential
3.4.2.4	Convey Guidance Commands	5.4.2.3.5	Determine Avoidance Maneuver
3.4.3	Control Environmental Information Sources	5.4.3.3.3.1	Control the Weather Awareness System
3.4.4	Convey Environmental Information	5.4.3.1.1.2	Convey Weather Information to the Pilot
Cross-Cutting			
3.5.1	Secure the Control Station	5.5.1.3	Prevent Unauthorized Operation of the UAS
3.5.2	Convey Health and Status	5.5.2.1	Identify System Status
3.5.3	Enable Contact With The Unmanned Aircraft	5.5.1.4	Provide Link Connectivity
3.5.3.1	Transition Between Modes of Operation	5.5.1.4.1	Transitioning between LOS/BLOS
3.5.3.2	Transition Between Different Operating Locations	5.5.1.4.2	Transitioning between Control Stations
3.5.4	Manage Contingencies	5.5.2.4.1	Enable the Pilot to Manage Contingencies

Table 2: Functional Requirements Verification Matrix

5 FUNCTIONAL REQUIREMENTS VERIFICATION MATRIX

Requirement	The Human System Interface shall:	Verification
Aviate		
3.1.1	Enable the pilot to command maneuvers	Demonstration
3.1.1.1	Enable the pilot to control the spatial orientation of the unmanned aircraft	Demonstration
3.1.1.2	Enable the pilot to control aviate systems settings	Demonstration
3.1.2	Convey information to the pilot to monitor maneuvers	Demonstration
3.1.2.1	Convey spatial information to the pilot	Demonstration
3.1.2.2	Convey aviate systems status to the pilot	Demonstration
Navigate		
3.2.1	Enable the pilot to control the navigation system	Demonstration
3.2.1.1	Enable the pilot to develop the mission/flight plan	Demonstration
3.2.1.2	Enable the pilot to operate the navigation system	Demonstration
3.2.1.3	Enable the pilot to update or modify the flight plan	Demonstration
3.2.2	Convey information to the pilot to determine the unmanned aircraft's position, ground track, and ground speed	Demonstration
3.2.2.1	Convey navigational information to the pilot	Demonstration
Communicate		
3.3.1	Enable the pilot to communicate with ATC	Demonstration
3.3.2	Enable the pilot to control the communication system	Demonstration
3.3.2.1	Enable the pilot to tune the radio to an assigned ATC channel	Demonstration
3.3.2.2	Enable the pilot to monitor ATC channel activity	Demonstration
3.3.2.3	Enable the pilot to transmit voice on the assigned ATC channel	Demonstration
3.3.3	Convey the status of the communication system to the pilot	Demonstration
Avoid Hazards		
3.4.1	Enable the pilot to control the CCA system	Demonstration
3.4.2	Convey information to the pilot to avoid cooperative aircraft	Demonstration
3.4.2.1	Convey the relative location of all cooperative aircraft within the CCA system's surveillance volume to the pilot	Demonstration
3.4.2.2	Convey the track profiles associated with any of the cooperative aircraft detected	Demonstration
3.4.2.3	Convey that the potential for a collision exists	Demonstration
3.4.2.4	Convey guidance commands to avoid the potential for a collision	Demonstration
3.4.3	Control environmental information sources	Demonstration
3.4.4	Convey environmental status to the pilot	Demonstration

Cross-Cutting		
3.5.1	Enable the pilot to secure the aircraft control station	Demonstration
3.5.2	Convey information to the pilot to determine the health and status of the UAS	Demonstration
3.5.3	Enable the pilot to contact the unmanned aircraft	Demonstration
3.5.3.1	Enable the pilot to transition between modes of operation	Demonstration
3.5.3.2	Enable the pilot to transition between different operating locations	Demonstration
3.5.4	Enable the pilot to manage contingencies	Demonstration

Table 3: Functional Requirements Verification Matrix